IDC School of Design अभिकल्प विद्यालय IIT Bombay

Instructional Design:

Morphology of Flowering Plants

Interactive Card Deck with illustrations as markers for Augmented Reality

Project Guide: Prof. Venkatesh Rajamanickam

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M.Des Interaction Design

Project Approval

Interaction Design Project 2 titled “Instructional Design: Morphology of Flowering Plants, Interactive Card Deck with Illustrations as Markers for Augmented Reality” by Zuha Asif P, (Roll Number 216330014) is approved for partial fulfillment of the requirement for the degree of ‘Masters in Design’ in Interaction Design at IDC School of Design, Indian Institute of Technology, Bombay.

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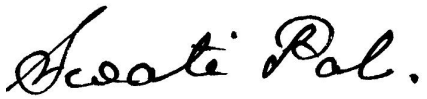
Internal Examiner: 
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Declaration

I declare that this written document represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea, data, fact, or source in my submission. I understand that any violation of the above will cause disciplinary action by the institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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Zuha Asif P

Abstract

This project aims to create an interactive experience for children to understand the morphology of plants. The deliverables are a deck of cards explaining concepts with the help of Augmented Reality(AR). The cards contain a brief of the classification type on one side and illustrations as image markers for AR models on the flip side. The models are also supported with Audio explaining the concept/ topic. This helps in demonstrating samples that are not easily available everywhere and are difficult to find in the nearby environment. It also helps to project realistic models of the plant to understand concepts better.
This is also aimed at creating interest in younger minds to develop an interest towards this subject, which invokes a child to observe the plants and trees around them and find patterns and arrangements.
To make this project I relied on Vuforia Engine in Unity. It allows the user to add animations, videos, and images under different parent image targets. This can be used by any Android device and does not require any additional hardware like a VR headset.

Contents

1. Introduction

Plants are everywhere - in different varieties, forms, and structures. The classification of plants is complicated due to their wide variety and forms. Morphology provides us with the basis for the understanding of function, taxonomy, heredity, ecology, development, and other parts of biology. Thereby giving us a platform to study other branches as well.
The reason why I have taken this topic is because I personally found it very difficult to learn and remember. The area that I have chosen to cover is leaf modification in the morphology of flowering plants. The plants and trees just outside our doorstep, on why certain roots, stems and leaves are modified to different forms to perform various other functions.
In the current system, teachers rely on diagrams to teach concepts and very few of them manage to get real specimens to study from observation. But all these wide varieties of plants are just around us and observing and identifying them is the key factor in this area.

In a typical classroom around 10% of students are intrinsically motivated and bright. They learn from the existing materials and manage to score top marks. Some students get a good amount of attention from parents and they are extrinsically motivated to learn. Very few students are able to relate, observe and learn. It is very important to

understand concepts and link them to daily life. This will only be possible through an active learning process. Currently, the textbooks are content overloaded with very few images and examples. It is difficult for students to visualize and remember in this case. The selected portion is from the 11th standard NCERT textbook with further additions and examples from external sources.

The current prototype is made for leaf modifications, which can be later extended to advanced portions like inflorescence, monocots, and dicots, etc.

2. About the Project

2.1 Aim

The main objective of the project is to make a product that would enable the student to quickly grab a basic understanding about the structural organization of plants, including the structural basis of physiological or behavioral phenomena, without the actual sample or any other external help like teachers.

The product also motivates children to form an interest towards this subject which requires more of an observational learning. The syllabus is taken from NCERT 11th std textbook, which is an advanced portion of 6th standard biology syllabus. The content is delivered in such a way that even younger students (6th grade onwards) can use and learn/ create interest towards the topic.

2.2 Target Audience

The target audience is school going children in the age group 11-16 years. Students are introduced to the basics of morphology in 6th standard. This will be an advanced portion delivered in an interesting manner to develop an interest towards the subject. This can also be used as a supplementary learning tool by the students of class 11.

3. Secondary Research

3.1 Understanding Plant Morphology

Plant morphology is defined as the study which discusses the structure of the various different plants. The plant morphology is also described as the plant anatomy as this is discussed about the structure of the plant. This process is very much effective in the visual identification of the trees or plants. The internal structure of the plant is analyzed by the microscopic analysis of the plants. These morphological approaches are also applicable in the parts of the plants like flowers, leaves and fruits. This process also helps in the classification process of the plants.

3.2 Importance of the subject

This helps to identify the internal and external structure of the various plants which helps botany to improve their study.

- As the study is comparative, it helps to identify various structures of the plants of different species.
- Study on somatic and reproductive structure of the plants helps to develop the research and advancements in this area
- The study is using a smaller scale to identify the smallest internal structure of the plants. This is

possible with the help of the Microprobe and this helps in the classification process.

- It also helps in the classification process by identifying the external and internal structure of the plants.
- Improved research is the plant morphology that also helps to improve research in the taxonomy and genetics fields.

3.3 Content Analysis

The content can be briefly classified into -

Monocots and Dicots, Root modification, Phyllotaxy, Stem modification, Leaf Modification, Inflorescence, Flower as a reproductive unit, and seed modifications.

Considering the vastness of the topic and scope of the project, the content was narrowed down to Leaf modification, which mainly includes Simple Vs Compound leaf, Different types of venation, and leaf Phyllotaxy. In the initial study, this was further grouped into different sections, which require detailed diagrams, activities, 3D models in support of auditory feedback, elaborate diagrams, videos, etc.

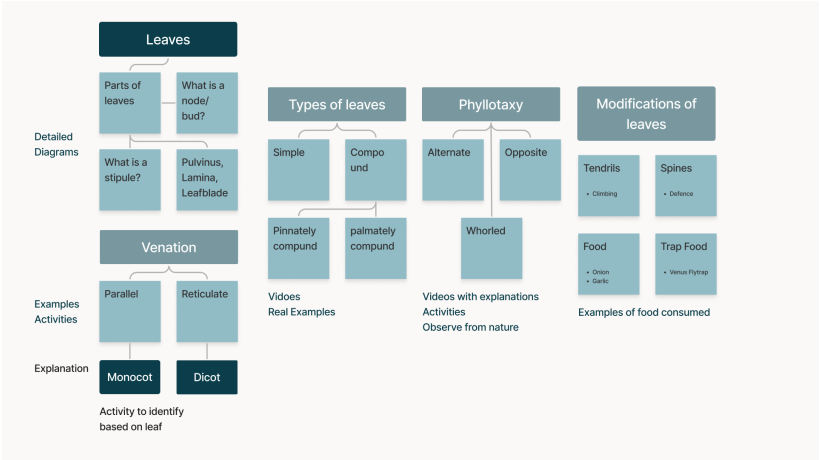

Fig. 1: *Chunking of information based on the type of explanation required*

3.4 Using Augmented reality in Education

Augmented reality (AR) is a technology that overlays digital information such as sounds, videos, and graphics on top of the real-world environment. It uses four main components to superimpose images on current environments: cameras and sensors, processing, projection, and reflection.

The use of AR in education has been extensively researched to help students with complicated subjects.

Activity Process

Before the activity started, students had been informed about AR and its activities for two lesson hours. To prepare the AR material, students installed the Aurasma (HP Reveal) program on their phones. Two-dimensional pictures on the materials prepared through Aurasma were introduced as markers. Then the animations or videos that would appear upon displaying these pictures were matched with the images. When students scanned these pictures via the Aurasma program with their mobile phones, they were able to see the generated multimedia materials on their screens. The researchers conducted an exemplary lecture with the support of AR for the students to understand the use of the program better. After explaining the life cycle in bryophytes, the life cycle chart (Figure 1 below) created with AR support on a worksheet was handed to the students. The students filled the worksheet by watching the animation created on the scheme through Aurasma.

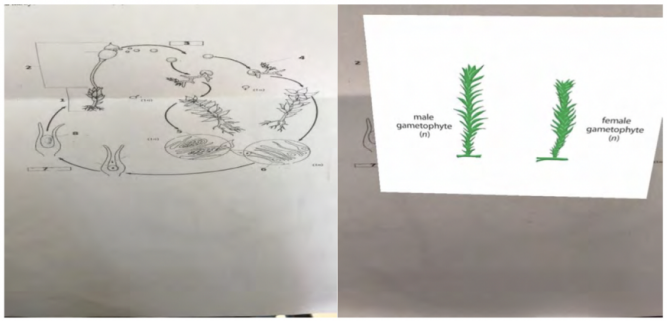

Figure 1. *AR-supported sample worksheet*

Fig.2: *Yapici & Karakoyun, F. (2021). Using Augmented Reality in Biology Teaching. Malaysian Online Journal of technology*

Yapici & Karakoyun, F. (2021) claim that MAR(mixed Augmented Reality) activities concretized the subjects, and they increased interest and motivation among students, where they conducted a study on using Augmented Reality in Biology Education. The study was designed as a case study. The study participants consisted of 16 prospective teachers. It was observed that future biology teachers mostly expressed positive thoughts about AR activities. Some advantages of the AR activities were as

Fig.3: *Arslan, R., Kofoglu, M. & Dargut, C. (2020); Usage of AR for learning about internal organs in a laboratory setup*

follows: concretizing the subjects; retention; being exciting and entertaining; repetition capability; and multimedia support.

Arslan, R., Kofoglu, M. & Dargut, C. (2020). The development of Augmented Reality Applications for Biology Education states that AR facilitates understanding in a 3D laboratory environment and increases students' motivation to learn. This paper has evaluated the student's engagement in the learning process. The fact that it is aimed at mobile devices is successful in terms of accessibility and ease to use.

As explained above there are several studies supporting the use of AR in education, and the scope ranges over a wide variety of topics. In certain areas, people use AR to avoid risk factors, which are hard to reach or difficult to touch. In Biology itself there are broad classifications - organisms that cannot be seen through the naked eye (micro level), Organs functioning and anatomy, which are not readily accessible and involves dissection - these can be shown through 3D models avoiding the risk of cutting, opening and dissecting.

Various activities have also been tried out using AR to facilitate engagement and retention of information.

AR technology can help teachers create lesson plans with multisensory experiences. Students benefit from immersive virtual content that incorporates an experiential learning style in which students carry out physical activities instead of watching a demonstration. This approach can help with sensory development. Bringing in the sense of depth and allowing to rotate objects physically helps students to actively engage in the learning process.

Unlike VR, AR does not require any additional equipment other than a smartphone, which adheres to the cost related issues. Thereby studies state that Augmented Reality in education is increasingly cost effective to execute in the current scenario.

4. Primary Research

4.1 Key Takeaways - High School Botany Teachers

I conducted my primary research with high school and higher secondary Biology Teachers who teach the topic “Morphology of flowering plants” to get a better understanding on the current method of teaching and the problems that they face in delivering the content. The key insights were as follows:

- Most of the teachers rely on diagrams that are given in the NCERT textbooks
- Difficult to find certain examples in nearby surroundings
- Lack of time to concentrate on activities
- Sometimes has to revisit younger class portions to explain concepts
- Teachers has to take the responsibility of bringing the samples to the class and explaining
- It is difficult to manage a class of strength 50 and more for a field trip to show examples
- Most of the times only a very few samples are available in the nearby environment
- Does not get enough time to plan activities in the current curriculum.

4.2 Key Takeaways - Class XI Students

I also interviewed students who have just completed the chapter to know about their learning experience. The summary of feedback received is as follows:

- The classifications are very vast and it is very difficult to remember
- Most often confused with the naming of different species and types
- Many topics are introduced all at once
- Textbook has limited number of examples
- Many topics are introduced all at once
- The subject was not taken in an activity oriented manner
- When students are asked to bring samples, they are confused about which one

From the user interviews taken from both sides, it was inferred that the content is very confusing and vast. There are no proper examples in the textbooks with supporting images, and when it comes to showing actual samples, it is difficult to find all the examples that are needed in the nearby surroundings.

This led to the idea of using AR as a supplementary tool to explain these concepts better, so that the teachers and children do not have to manually go outside and collect samples in case of difficult situations. This will also increase curiosity and also a third dimension of engagement.

5. Design Ideas

5.1 Active Learning Technique for Botany Education in Campus Environment using open source web GIS application

The initial idea was inspired by the spectacular flora and fauna of the IIT Bombay Campus, which has a wide variety of flowering and non flowering plants, which very few people know about in depth.
Most of the trees are marked and information regarding the same are printed on a laminated paper, but most of them are not easily reachable and it is not done in a user friendly manner.
The initial exploration was to select an area in campus and geotag all the plant species in that area, and document the relevant information such as Distribution, Classification, Flowering period, Economical importance etc.
Problems Identified

- There exist a platform Greenopedia run by NSS IIT Bombay, which has marked major trees and recorded useful information
- In a small area, GPS accuracy was an issue
- To observe details like flowering and other characteristic features requires data over a long period of time, which was out of scope of the project

- Collecting large data and compiling for the purpose of campus archive will also require contributions from more users, which is also out of scope of the project.
- It is very difficult to make a field guide by generalizing classifications as the portion is very broad.

Considering the problems identified and questioning the novelty of the idea, it was discarded and moved forward to explaining the concept of plant morphology in a fun and engaging way.

5.2 Interactive Booklet with illustrations as markers for Augmented Reality

Learning about AR and its benefits helped me come up with the idea of using the technology to show examples of actual plants by replicating 3D models of them and showing them with the help of Augmented Reality.

In this case the students don't have to manually go and collect plants from immediate surroundings. The idea was to design an interactive booklet which acts as a supplementary material for class XI students and also as a fun learning material for classes VI and above to form an interest towards the subject.

6. Design Process

To begin with I started observing the plants and trees around me to find recurring patterns and commonly found plants. Later on, I researched methods to replicate these in 3D models. One of the best ways to convert an object in the real world to 3D is photogrammetry. But since leaves are mostly two-dimensional the accuracy of leaves in photogrammetric models was doubtful.

6.1 Photogrammetry

In order to show the 3D models of actual plants around us as live examples for different leaf classifications, they were scanned in 360° in vertical position and from lower and upper angles. These images were combined together to produce the 3D model. The photos are taken from different locations and angles to allow for precise calculations that help analysts gather the data they're looking for. Typically, they use things like photo interpretation and geometric relationships to gather measurements. With the data gathered from photogrammetry, we can create maps and 3D models of real-world scenes.

However, there are some limitations in photogrammetry as the size of the specimens are too small and the leaves are generally 2D. Due to this, the models are not very precise

and realistic as how it is supposed to be. But the texture and arrangement comes out up to 90%.

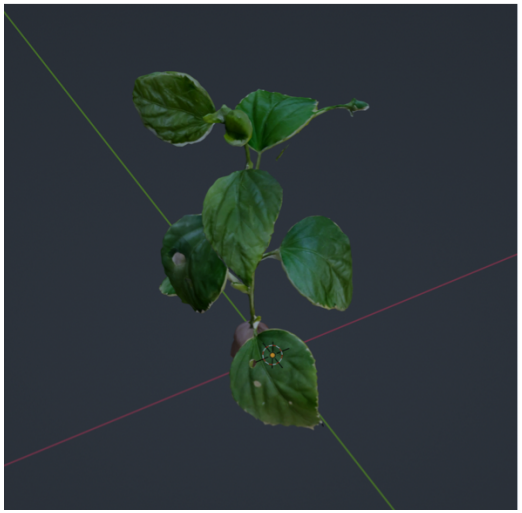

Fig.4: *Photogrammetric model of Hibiscus Plant*

The figure mentioned above shows a photogrammetric 3D model of a hibiscus plant. Though the texture has come out well, there are some gaps between the leaves. Even the edges of the leaves are not sharp due to the superimposition of the texture of the table on which it was mounted.

As the models become smaller wherein leaves are closely spaced, the elements tend to get superimposed to each other.

Problems Identified:

- Identifies surroundings as a part of the model.
- As models become minute, the clarity in the model decreases
- Depending on the scale of the plants, not all of them can be cut and shot - inconvenient for larger plants
- Lighting is a major issue while shooting
- Time-consuming
- Once a model is generated, making modifications using any 3D software is very difficult.

6.2 3D Modeling using Blender

3D modeling of plants in Blender tends to be more effective than photogrammetry as it generates better models in terms of clarity. The nodes and arrangements of leaves can be better understood in 3D models. Image textures are added from scanned images of actual leaves into the model. To create a sense of depth, a bump map and a normal map are used.

A total of 15 models were made, which include:

- 4 models to show the different types of phyllotaxis

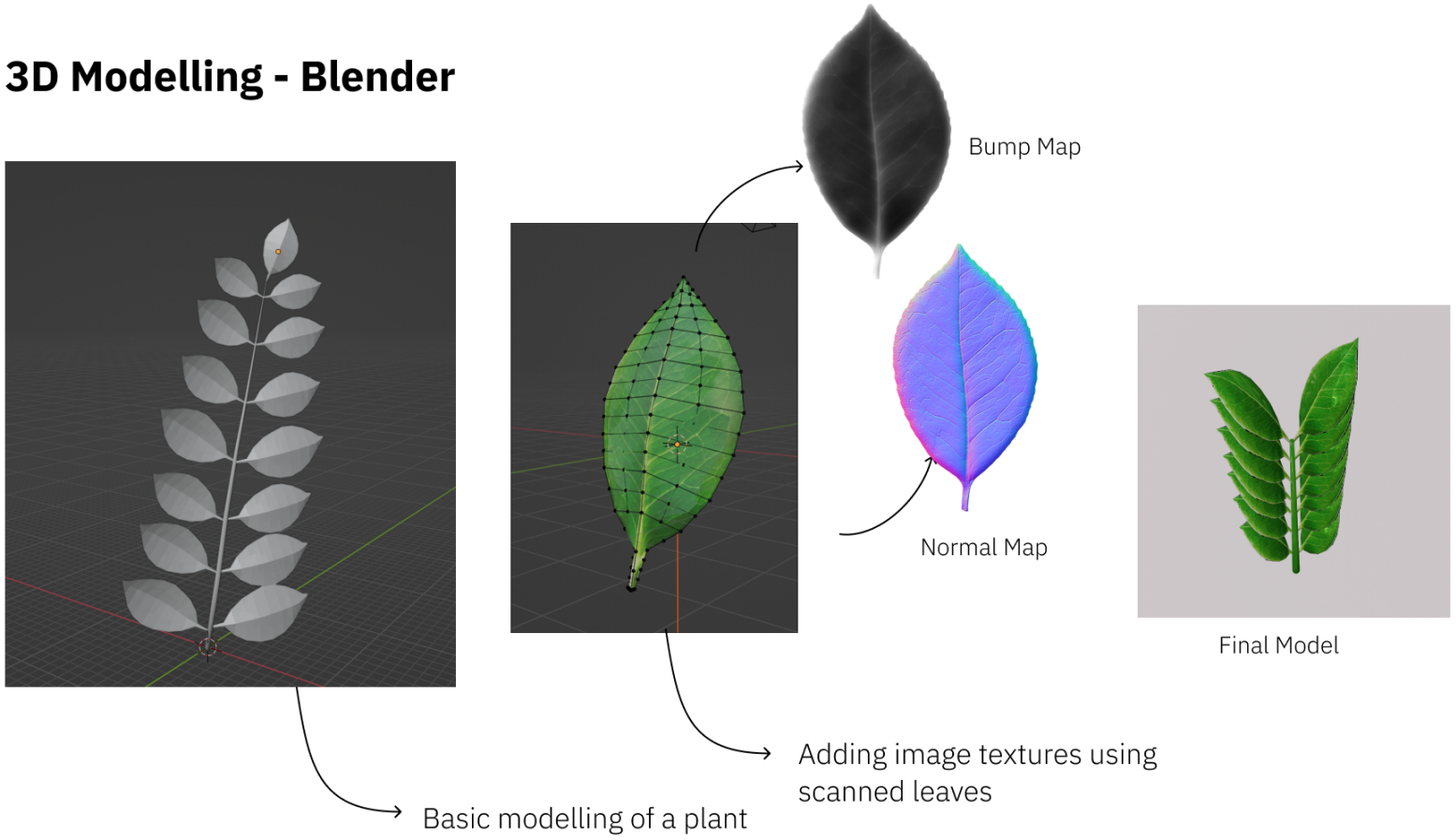

Fig.5: *The figure shows the overall process of modeling plants in blender and adding image textures*

- 5 models to show the arrangement of leaves in different types of compound leaves
- 6 models to show examples of Parallel and Reticulate Leaves

These models are sculpted manually taking reference images of leaves, and later image textures are added by adding a normal map, bump map and a base map in unity. Thereby the vein structure and other minute details can be observed through the model.

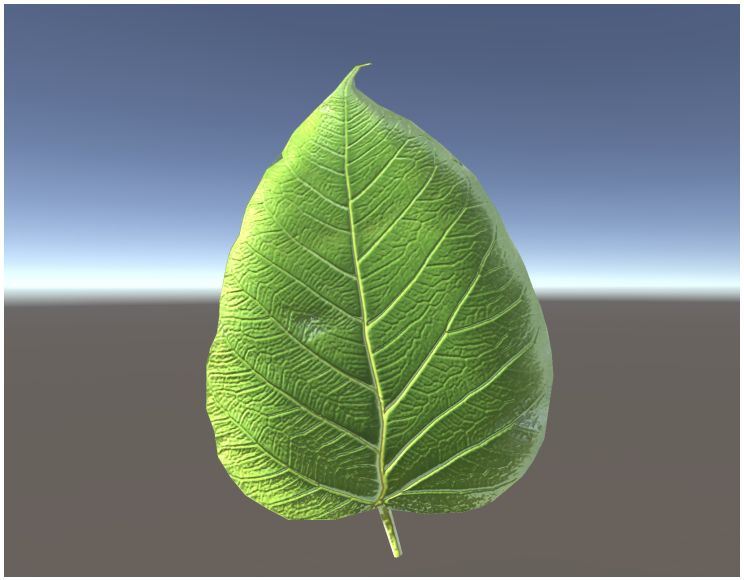

Fig.5: *Blender model of a Peepal leaf to show the Reticulate Venation pattern in unity engine*

In the above figure of the 3D model of Peepal leaves, the vein arrangement can be clearly observed with the help of image textures.

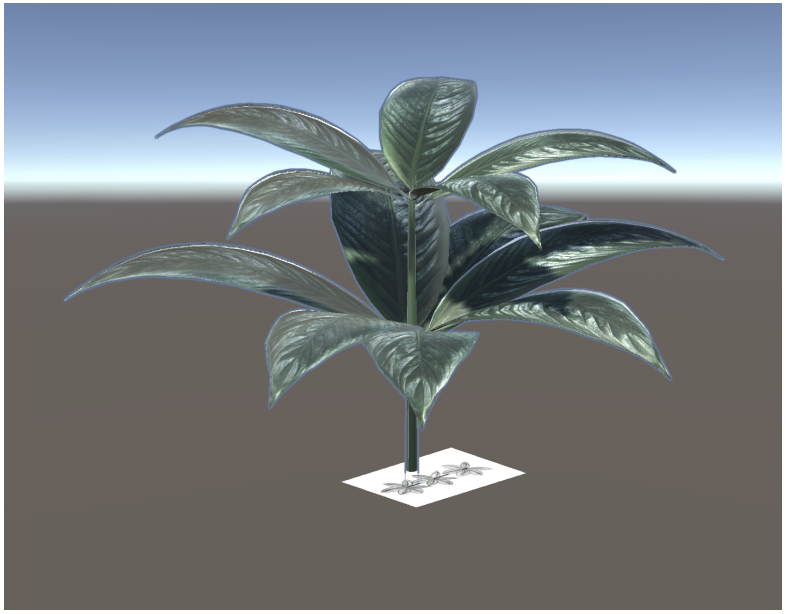

Fig.6: *Blender model of a plant to show whorled phyllotaxy in unity engine*

The figure above shows the image target and linked game object in unity. On rotating the target or moving the target the model also moves and the other parts can be analyzed.

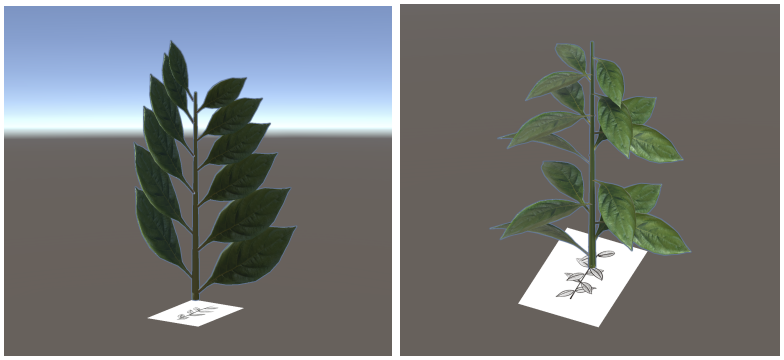

Fig.7: *Blender model of a plant to show alternate and spiral phyllotaxis in unity engine along with its image target at the base*

6.3 Unity Real-time Development Platform

I used Unity for developing my application to integrate 3D models into the actual environment. AR foundation allows you to work with augmented reality platforms in a multi-platform way within Unity. This package presents an interface for Unity developers to use but doesn't implement any AR features on its own. There are several plugins that can be installed on target devices that facilitate AR development. I have used Vuforia Engine in Unity to add models to image targets.

6.4 Vuforia Engine

Vuforia Engine is a software development kit (SDK) for creating Augmented Reality apps. With the SDK, you add advanced computer vision functionality to your application, allowing it to recognize images, objects, and spaces with intuitive options to configure your app to interact with the real world.

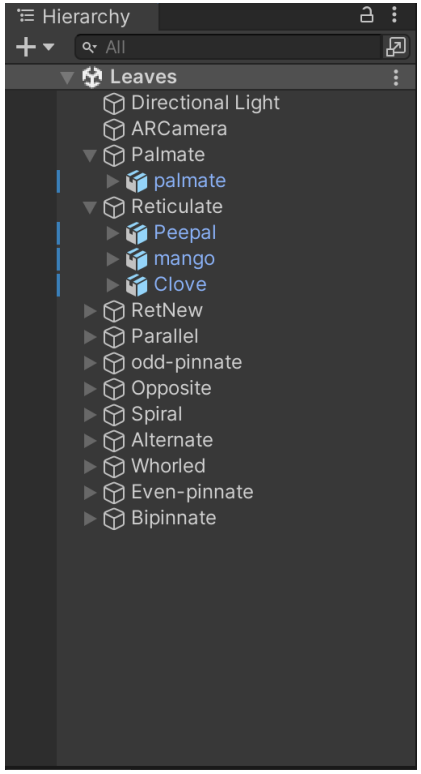

Fig.8: *The image shows the hierarchy window, where all the game objects and image targets are displayed. Here Reticulate represents the image target and Peepal, Mango, and Clove are a child of it.*

Vuforia Engine allows to add image targets as markers, these markers can be linked to different game objects. In my case, these game objects are the different plant models that I want to display when an illustration is detected.

When a game object is added as a child of an image target, it appears on target detection. Multiple objects can also be added to the same image target and these can be switched using buttons on the screen.

Unity also allows you to create multiple scenes. UI buttons can be used to switch from one scene to the other. In my project, I have used Buttons to change between different examples of Reticulate and Parallel Venation. Thereby with one single marker, multiple examples and images can be shown and these can be managed by buttons.

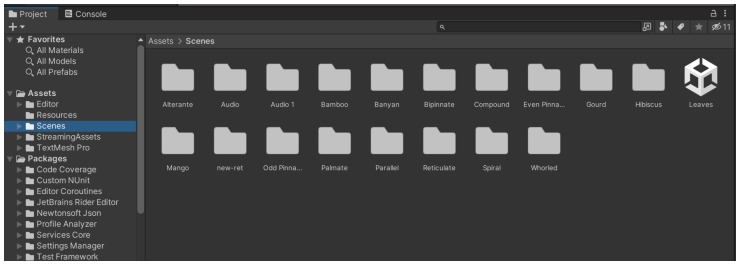

Fig.9: *Figure shows all the models, audio files and images under assets.*

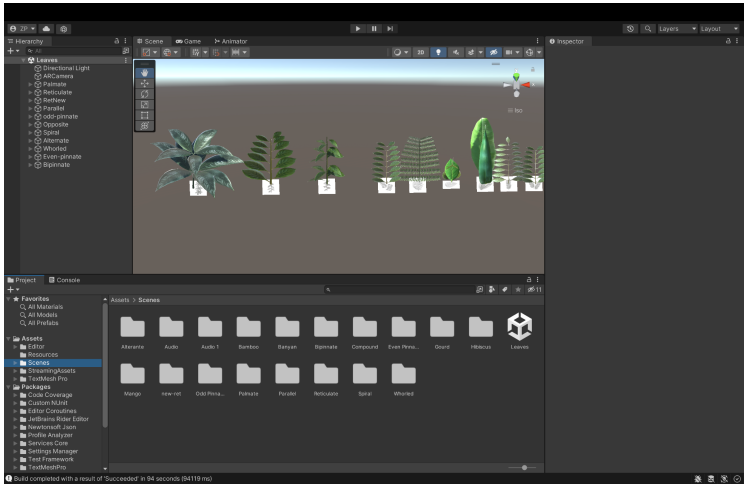

Fig.10: *Figure shows all the models, audio files, and images under assets.*

6.5 Scripting

C# scripts are added for controlling on-screen buttons and to control audio feedback depending on the type of image target.

6.6 Image Targets

Line drawing illustrations were made for each model to act as markers. These are made in black and white in order to have higher contrast for easy detection. The drawings are

an abstract representation of what the plant actually looks like.

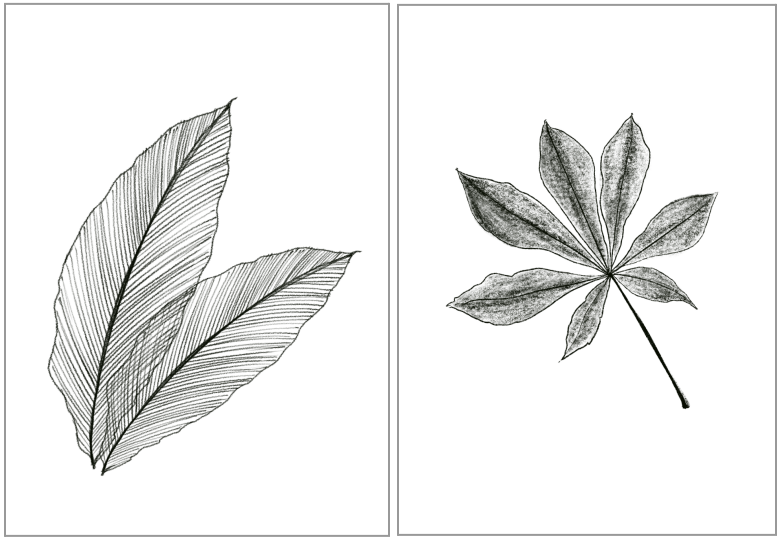

Fig.11: *Figure shows sample markers for models*

6.7 AR Booklet

In my initial iteration, I designed a booklet, which has the designed markers embedded inside along with related information and activities.

The idea was to use this booklet as supplementary material for the students of class XI and also for the younger class to form an interest in the subject.After testing with

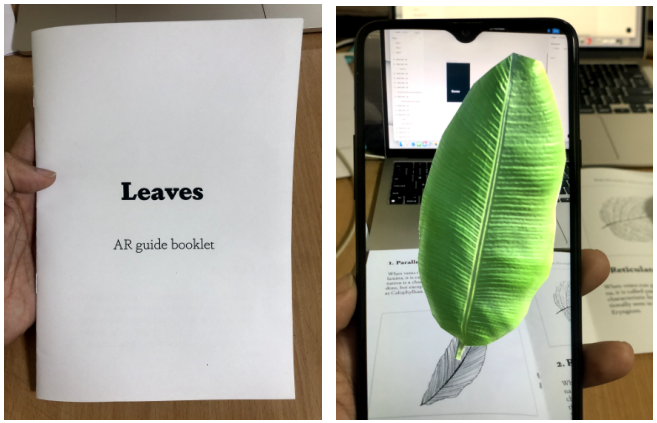

Fig.12: *Figure shows all the models, audio files and images under assets.*

users, it was observed that it is difficult to rotate the markers when the content is printed on a booklet. In order to rotate, the entire booklet has to be rotated which causes inconvenience. It was also observed that the models shakes extensively when printed on paper. This led to rethinking the format of print media into card decks.

7. Final Design - Interactive Card Deck

Fig.13: *Final Card Designs*

As a final prototype, Card Decks were designed with information on the type of venation/ leaves on one side and image markers on the other.

7.1 How does it work?

In order to start with, the users should download an APK file and install the application on their Android devices. Once installed the deck cards have to be placed anywhere, where there is ambient lighting to detect the markers. The user can point towards any marker depending on what they want to learn to get more information on the same. Once the image target is identified, models that are linked appear on the screen. These can be rotated or moved by moving the cards. Once the card is not in the vicinity of the camera, the object disappears. The user can now point toward the next target to view the next model.

In certain examples like leaf venation, there are on-screen controls to move on to the next example under the same image target. Thereby several examples from the environment can be demonstrated to get a better understanding of the topic. This will also encourage the child to observe them the next time, when they actually come across the same plant in the surroundings.

Fig.13: *The diagram shows the overall working of the product.*

7.2 Design Decisions

In order to differentiate between the different types, they were color-coded into shades of green and brown. In the prototype, all the classifications of compound leaves were designed in brown colored cards, whereas venation was color coded into light green, and Leaf Phyllotaxy was designed in dark green cards.

This is done for easy identification. The card dimensions are of 2.5*3.5 inches which is the standard size of Card Decks. A small button is given at the bottom to highlight the type of classification.

7.3 Evaluation

The final product was shown to the class XI Biology teachers who teach the subject. They were asked to explore the prototype and think out loud. Some of the key insights from their feedback are as follows:

- Fascinated by the technology and inferred that AR has never been used in the classrooms
- These cards can be distributed as an instructional package along with the textbooks
- Audio feedback is helping in making the experience better
- These models are very helpful in showing the arrangement of leaves in phyllotaxy, most often teachers find it difficult to find actual models around them
- Cards are handy and useful
- Suggested to extend this method over topics such as inflorescence, seed modifications - dicots and monocots
- Remarked that this method can be very useful if extended to teach cut cross sections of flowers and seeds.

A more detailed evaluation study was conducted on class XI students who have already studied these concepts to understand their level of understanding and engagement.

The observations from the test were as follows:

- Students were very curious to see the models.
- They recalled from what they have learned while seeing the models
- Could navigate through examples very well
- Could listen to the audio and observe the models together
- They explored rotation, zooming into the models and flipping through various examples
- They used buttons to change models without any external help

The Feedback from the students after using the product are:

- Remarked that it would be great to use this as a supplementary material while learning the chapter

- Curiosity in new technology is making subject more interesting
- On screen controls to zoom would have been helpful
- Extension of this method to learn about cut cross sections of flowers and seeds would be very helpful
- Repeat audio option on the screen would have been helpful
- On screen labellings about the models would make it more interactive

The product was tested on students who opted computer science in XI grade and does not have a prior knowledge of the topic to understand if they are able to get the concept. The Feedback from the students was as follows:

- Was able to understand the concepts through the model
- Audio repeat option would have been useful
- Extra information about the plants could have been included
- Helps in quick learning about the arrangement of leaves
- Were able to navigate easily and understand the color coding
- Auditory Feedback for individual examples

From the evaluation it was noted that the students really engaged and enjoyed the process of learning. They were interested in the technology due to its novelty. The topic that I have selected and the models that were modeled were mostly basic considering the time scope of the project. It was noted that the students and teachers suggested even more complex topics to be taught in the same method. These were mostly parts of a plant or cross sections that are very small and cannot be seen easily with the naked eye or dissected without professional help. There were a couple of glitches as well in the prototype which have to be corrected for a better experience.

8. Conclusion

This project explored bringing Augmented Reality into the current NCERT syllabus. Literature review helped me categorize the subject into various subsections, which require the use of Audio, Video, or Visual experience. The use of AR in teaching showed increased curiosity among the users, which has not been explored much in the current schooling systems. For the scope of this project, only a small part of the topic “Morphology of Flowering Plants” could be explored, which is the leaf modification, venation, and phyllotaxy. Whereas this method can be extended to all other topics which require observational learning as suggested by the feedback of the teachers.

My prime intention behind this project was to bring children closer to nature with the same technology that led them away from nature. It was observed that the level of engagement they showed from a qualitative evaluation of how the users interacted with my product is positive and a level higher than the normal textbook learning.

9. Future Work

This project has a lot of scope and potential if expanded in the right direction. After conducting an evaluation and according to the feedback from the users and higher secondary teachers, I have come up with a set of improvements to be made so that this technology can be exploited in a much more effective way. This includes:

- Adding more features on the screen such as Zoom, and labeling the different parts of models as and when required.
- Add separate audios for each example
- Develop this method for difficult topics - as suggested by students and teachers.
- Include audio prompts as activities to find similar plants
- Add models in exploded view format, where students can see each part in detail and also switch between them, This will also be scaled from the actual sizes.

10. Reflections

In the recent past I developed a profound interest in nature and found it very inspiring. I started noticing minute details of nature around me. And one such domain was the plethora of plants around me. The fact that it did not interest me when I was a kid, made me reflect on my childhood. This set a background for my thoughts regarding what I want to work on for the children. The main motivation for me was to build something so that the younger minds also start observing and appreciating nature as I started very recently.

In the current world scenario, children are not encouraged to explore plants or play with mud or anything that our ancestors did, but rather the focus is on new technology. Everything is going toward the metaverse. Even in school biology classes, most of the concepts are taught maximum with a diagram or a video, which does not add up to the engagement.

Along the course of the project, I myself started collecting leaf samples which made me even closer to nature. Now how to put this idea into young minds was even more challenging, I tried various methods as I have explained in the report before. I realized that it is the technology that is taking children away from nature, and I experimented with using the same technology to bring them closer to it.

For that, I modeled plants and leaves and tried to make it realistic using various trial-and-error procedures to bring in the next level of interactivity.

In the process, I also learned various new techniques like photogrammetry for capturing realistic models, Blender for modeling from scratch, Unity for compiling and making an application, and also brushed up on my coding skills to integrate all of this together. I also used audio prompts to encourage students to next time observe the nature around them and find samples that are similar to the ones that they are viewing with my solution.

From my brief qualitative observation of the first set of users, I observed that they were very very curious and impressed by the method by which the content was delivered and I also noticed a higher level of engagement in them. My learning curve during the whole process was very drastic and iterative, and I thoroughly enjoyed the process.

11. References

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